EVALUATING IMPACTS OF STREAM FLOW ALTERATION ON WARMWATER FISHES

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ABSTRACT

Preserving diverse stream communities depends on maintaining habitat integrity in the face of continuing water resource development. Research conducted through the Auburn Field Station of the National Ecology Research Center currently addresses problems that confound impact assessment for warmwater stream habitat. Investigations of habitat requirements of fishes and invertebrates, transferability of habitat criteria among stream systems, and broader habitat-based methods of impact assessment are underway with the ultimate goal of improving our ability to predict effects of flow regulation on warmwater stream biota.

INTRODUCTION

Increasingly, water resource managers must consider potential effects of development projects on stream communities. As a consequence of extensive habitat destruction, primarily through impoundment and siltation, a growing number of riverine species receives protection under the Endangered Species Act. In Georgia, six freshwater fishes are listed as threatened or endangered (with an additional 14 species currently in status review), and nine mussel species are proposed for listing. Georgia recently granted 55 fishes protected status at the state level. Jeopardized species reflect the greater problem of habitat loss. Preserving biotic diversity in warmwater streams will require maintaining and restoring suitable instream habitat in the face of continued water resource development. Achieving the goal of preserving biotic diversity requires accurate methods for assessing habitat requirements of aquatic communities and predicting impacts of proposed development projects.

The National Ecology Research Center (NERC, U. S. Fish and Wildlife Service) established a field station at Auburn University, Alabama, specifically to develop methods for evaluating impacts of altered flow regimes on warmwater stream biota. We describe some of the problems of impact assessment currently under research through the NERC-Auburn station, and we discuss future research needs.

ADAPTING THE IFIM TO SOUTHEASTERN STREAMS

The Instream Flow Incremental Methodology (IFIM) offers a process through which managers can evaluate and compare effects of alternative flow regimes on instream habitat for target species (Stalnaker, 1979; Bovee, 1982). The methodology requires knowledge of species-specific habitat requirements and data on channel structure and discharge-stage relationships for the stream section where flow will be regulated. With these data, the IFIM allows one to analyze how incremental changes in flow regime will affect instream habitat for target species. This ability to quantify trade-offs between habitat and flow-modification represents a major advantage of incremental over standard-setting approaches (e.g., setting minimum instream flow at the 7-day Q10).

The IFIM has been criticized primarily because it assumes direct relationships between availability of suitable habitat for target species (usually fishes) and their population densities (see review by Orth, 1987). If populations are limited by food availability, competitors, predators, or pathogens, then population densities will not closely correspond to habitat availability. Nonetheless, stream habitat provides the template for community interactions; the key to successful impact assessment lies in identifying habitat components critical for maintaining stream communities.

Challenges to applying the IFIM (and to impact assessment in general) in warmwater streams include high species diversity and inadequate data on habitat requirements for most species. Research currently funded through the NERC-Auburn field station includes (1) evaluations of species-specific habitat requirements and (2) development of alternative habitat-based methods of impact assessment (Table 1).

RESEARCH UNDERWAY

Quantifying fish-habitat relationships

Habitat requirements by stream fishes commonly are quantified through direct fish observation, by snorkelers or divers, coupled with measurements of water depth, current velocity, substrate and cover at fish locations. However, high turbidity in most southeastern streams limits underwater observation. Prepositioned area shockers (PAS's; Bain et al., 1985; Bovee, 1986) offer an alternative method for sampling fish and associated microhabitat components. The PAS's use remotely powered electrodes, either suspended in the water-column or placed on the stream bottom, to ambush fish in a discrete area. After applying power to the electrodes and collecting stunned fish, investigators quantify water depth, current velocity, and other microhabitat variables in the sampled area. Scientists in the Alabama Cooperative Fish and Wildlife Research Unit used PAS's to quantify habitat use in diverse fish assemblages in seven medium-sized Alabama streams (mean annual discharge = 3-7 m^3/s; Knight et al., 1991). The method effectively sampled a wide range of species and sizes, even with short shocking times (20-30 s) in small (≤ 3 m^2) areas. For example, we used this procedure to sample Piedmont and Coastal Plain streams in Alabama during summer 1992. We captured an average of eight individuals and three species per sample (n = 87 samples) in Hatchet Creek, a Piedmont tributary to the Coosa River. We collected 25 fish species from Hatchet Creek, including juveniles and adults ranging from <20 mm to >200 mm standard length. The method probably sampled a large portion of the fish assemblage present.

Advantages of sampling with PAS's include the ability to make positive species identifications (sometimes difficult in underwater observation) and to collect microhabitat data simultaneously on several species, both important attributes when working in speciose systems. The method is time-consuming, however, and a prohibitively large number of samples may be required to attain sufficient data for less common species. For example, 16 of the 25 species we collected in Hatchet Creek during summer 1992 were represented by fewer than 20 individuals.

The greatest limitation of PAS's is their restriction to relatively low-flow conditions. Our PAS is effective in depths to about 1.2 m. If fishes shift among habitats with changing flow conditions (or seasons), then habitat suitability data based on low-flow periods will not adequately reflect overall habitat requirements. Methods for quantifying habitat-use during higher-flow conditions, and in deeper streams and rivers, remain a critical need for impact assessment.

Problems of criteria transferability

The extent to which habitat use depends on local conditions or biotic interactions determines the validity of applying habitat criteria developed in one stream to other sites. Recent research by the Virginia Cooperative Fish and Wildlife Research Unit evaluated transferability of habitat criteria for smallmouth bass between two Virginia rivers. A study underway at the Auburn field station is evaluating transferability of criteria for non-game fishes among Piedmont and Coastal Plain streams in Alabama.

The expense of developing habitat suitability criteria for all target species, or even for groups of species (e.g., guilds), in each future impact assessment underscores the need for alternative approaches. Knight et al. (1991) concluded that variation in microhabitat use by fishes among seven Alabama streams made development of general species-specific criteria infeasible. Knight and coworkers identified important areas of instream habitat and broadly defined five habitat types (e.g., shallow-slow, shallow-coarse) with relatively distinct, but not exclusive, fish assemblages. Knight and coworkers currently are testing the hypothesis that assemblages in particular habitat types respond more strongly to flow regulation. This could lead to a method of impact assessment that models incremental changes in availability of particular habitat types rather than examining habitat availability on a species-specific basis.

Habitat requirements for invertebrates

The diversity and functional importance of stream invertebrates require that impact assessment include potential effects on invertebrate assemblages and production. Investigations currently underway at the Tennessee Cooperative Fish and Wildlife Research Unit include identifying habitat requirements for freshwater mussels and their fish hosts in the upper Cumberland River. This project also will develop criteria for impact assessment on mussel populations. Research at Auburn University on hydrologic relations of benthic macroinvertebrates in Alabama Piedmont and Coastal Plain streams (Webber et al., 1992) aims to incorporate invertebrate populations into impact assessment models. Invertebrates play a major role in energy flow in streams and constitute the primary food base for stream fishes. Future methods of impact assessment must consider not only microhabitat requirements for target species, but also habitats essential to system productivity.

Table 1. Selected projects currently funded through the National Ecology Research Center, Auburn Field Station.

Project (Research agency)	Completion date
Fish habitat relationships in Piedmont and Coastal Plain Streams (NERC-Auburn)	Jun. 1993
Transferability of habitat criteria for smallmouth bass (VA Coop. Res. Unit)	Jan. 1993
A habitat-framework for assessing effects of stream flow regulation on fish (AL Coop. Res. Unit)	Oct. 1994
Instream flow needs for common and endangered freshwater mussels (TN Coop. Res. Unit)	Feb. 1993
Benthic macroinvertebrate-hydrologic relations in warmwater streams (Auburn University)	Sep. 1994

CONCLUSIONS AND RECOMMENDATIONS

Fish-habitat relationships. Additional research on the degree of transferability of habitat suitability criteria will be required before we can confidently apply criteria among streams. We need better information on habitat requirements for sustainable reproduction, on life-stages or seasons when species are most vulnerable to habitat limitation, and on the appropriate spatial scale for determining fish-habitat requirements (Bain and Boltz, 1989). Ultimately, stream ecologists need to identify functional mechanisms underlying habitat requirements of target species and for generally maintaining biotic integrity. Although a species may commonly occur in a specific habitat, those conditions may be neither necessary nor sufficient for maintaining the population.

Alternative habitat-based methods of impact assessment. Identifying those components of instream habitat critical for maintaining diverse aquatic communities poses a major challenge to successful impact assessment. The problem of assessing impacts on diverse communities may be reduced by analyzing potential effects on habitat types rather than on individual species. However, any new approach should retain two key elements of the IFIM: use of biologically relevant criteria and ability to analyze effects of incremental changes in stream flow. Future efforts of NERC in the southeastern United States will focus on developing comprehensive methods for evaluating impacts of stream flow alteration on warmwater stream communities.

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